

Forest Conditions

ICP Forests
2017 Executive Report



2017

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United Nations Economic Commission for Europe, Convention on Long-range Transboundary Air Pollution, International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

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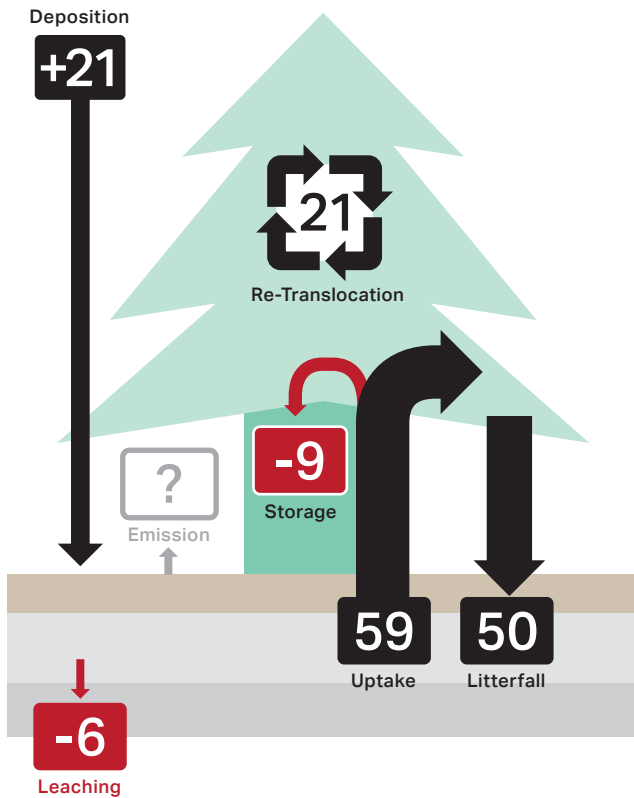


Figure 2-2: Mean annual nitrogen fluxes (kg N ha⁻¹) for the period 1991–2015 based on data from 22 Level II (intensive) forest monitoring sites in Bavaria, Germany. Arrow thickness is proportional to flux value.

Besides calculating nitrogen inputs/outputs to/from forest ecosystems over the past 25 years based on measured data, the study also looked at nitrogen cycling within forest ecosystems. The calculations were based on data from various Level II surveys: including deposition data, meteorological variables, soil chemical and physical values as well as information from soil solution chemistry, forest growth and the nutrient content of foliage and litterfall. Measured data were used to model water budgets and estimate nitrogen fluxes. Results show a total deposition of about 21 kg N ha⁻¹ a⁻¹ to these central European forest ecosystems. Losses through leaching from the soil (6 kg N ha⁻¹ a⁻¹) and net uptake by trees based on the annual increment of woody biomass (9 kg N ha⁻¹ a⁻¹) were similar. An ongoing nitrogen accumulation of 6 kg N ha⁻¹ a⁻¹ was calculated for the forest ecosystems studied.

Nitrogen cycling within forests is very high. The flux through annual litterfall varies widely (average 50 kg N ha⁻¹ a⁻¹), and is lowest for pine stands (20 kg N ha⁻¹ a⁻¹) and highest for oak stands (70 kg N ha⁻¹ a⁻¹). Foliage uptake also varies widely (average 60 kg N ha⁻¹ a⁻¹), and is again lowest for pine (30 kg N ha⁻¹ a⁻¹) and highest for oak (110 kg N ha⁻¹ a⁻¹). These data reveal a mean

re-translocation ratio of 21 kg N ha⁻¹ a⁻¹. Despite the continued net uptake of nitrogen by forest soils, there was no clear tendency for an increase in internal fluxes over the 25-year study period.

Although the potential for loss of nitrogen by gaseous emission from the forest soils due to denitrification is not yet quantified, this nitrogen budget indicates ongoing nitrogen accumulation within the forest ecosystems in Bavaria. This highlights the problem of ongoing nitrogen saturation found in many central European forests.

2.2 Nitrification in tree canopies

After more than 20 years of continuous monitoring at the ICP Forests Level II (intensive) monitoring plots, it is clear that tree canopies play a significant role in both intercepting rainfall and altering its chemical composition, thus affecting the nutrient input to the soil. Significant differences in terms of nitrogen fluxes have been observed between rainfall in the open field and below forest canopies (so-called throughfall) at many sites. However, the processes responsible for these differences are still unclear.

In an earlier study, nitrogen fluxes (particularly nitrate, NO₃) were examined in combination with stable nitrogen (δ¹⁵N) and oxygen isotope compositions (δ¹⁸O, δ¹⁷O) of NO₃ in rainfall and throughfall. This approach provided the first unequivocal isotopic evidence that biological nitrification, i.e. microbial transformation of ammonia (NH₃) or ammonium (NH₄) to NO₃, occurs

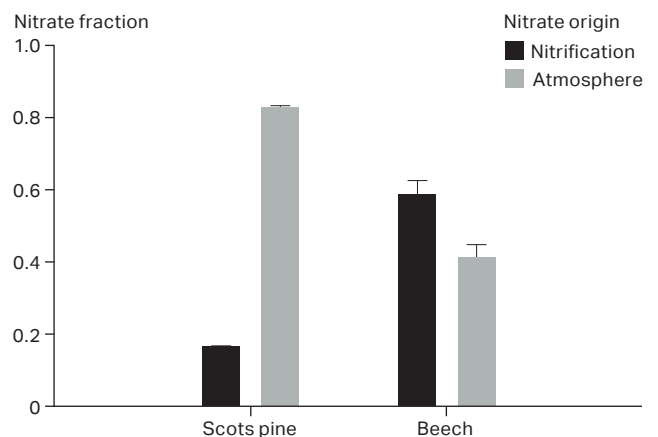


Figure 2-3: Relative fractions of nitrate (NO₃) originating from nitrification and the atmosphere based on the stable oxygen isotope compositions (δ¹⁸O and δ¹⁷O) of NO₃ in rainfall and throughfall collected during the 2011 growing season at a Scots pine forest stand and a common beech forest stand in the United Kingdom. Data show mean ± standard error.

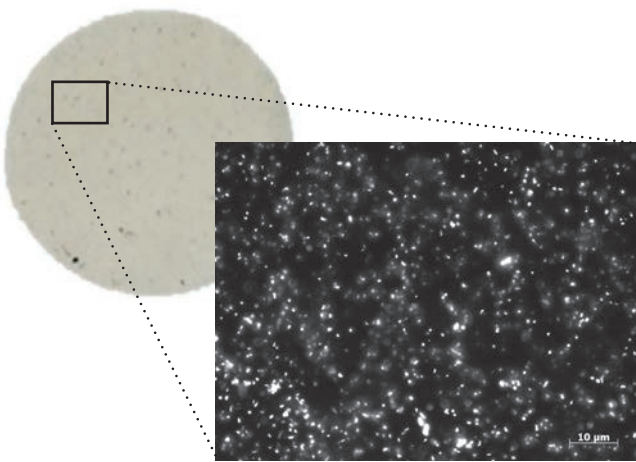


Figure 2-4: One of the 0.2 µm pore size polycarbonate filters used to filter throughfall at a site in Spain, plus an image obtained by epifluorescence microscopy on DAPI-stained cells showing bacteria (white dots) on part of the filter. Observations were made by Joan Cáliz and Mateu Menéndez-Serra (Centre for Advanced Studies of Blanes, Spain).

on the surfaces and/or inside leaves or needles (the so-called phyllosphere) in tree canopies (Figure 2-3). Biological nitrification was responsible for changes in the amount of NO₃ in throughfall versus rainfall at two UK forest sites receiving high atmospheric nitrogen inputs. This strongly suggests that microbes (bacteria and/or archaea) living in the phyllosphere control important pathways of nitrogen compounds in tree canopies. As microbes are mainly connoted with their role as pathogens it seems that there is still much to be understood about their effects on nitrogen cycling.

The current study has two aims. First, to characterise bacterial communities within tree canopies for common beech (*Fagus sylvatica*) and Scots pine (*Pinus sylvestris*) using meta-genomic techniques and to identify those

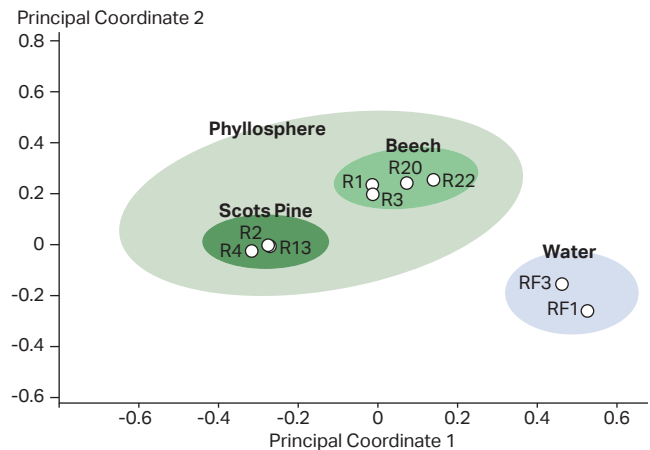


Figure 2-5: Results of a multivariate ordination analysis (NMDS) showing clustering in the bacterial communities of different sample types. Samples with similar community composition form 'clusters', such as phyllosphere (i.e. leaves and needles) versus water (i.e. rainfall or throughfall), and Scots pine needles versus common beech leaves.

microbial groups related to nitrogen cycling. Second, to quantify the proportion of NO₃ flux originating from bacterial activity in tree canopies relative to that from atmospheric deposition, by combining nitrogen fluxes with measurements of nitrogen and oxygen isotope ratios in NO₃ from rainfall and throughfall. The study includes six common beech and six Scots pine ICP Forests Level II (intensive) monitoring sites along a climate and nitrogen-deposition gradient from Fennoscandia to the Mediterranean area.

Preliminary results from metagenomic analyses on a subset of sites revealed the presence of bacteria in throughfall (Figure 2-4), with over 300 species identified. Bacterial community composition was clustered for rainfall and throughfall versus phyllosphere, and for

Terminology

Isotopes are atoms of an element, such as nitrogen (N) or oxygen (O), that have the same atomic number (number of protons), but different atomic mass (total number of protons and neutrons). The **stable isotope composition**, i.e. the so-called delta (δ) notation, is the isotopic ratio (¹⁵N/¹⁴N, ¹⁸O/¹⁶O, ¹⁷O/¹⁶O) of the analysed samples relative to an internationally accepted standard as: $\delta^{xx}E = (R_s/R_{St} - 1) \times 1000$, where E is the element of interest (such as N or O), ^{xx} is the atomic mass of the heaviest isotopes (i.e., ¹⁵N, ¹⁸O, ¹⁷O), R is the isotopic ratio (e.g., ¹⁵N/¹⁴N) of the sample (S) and the standard (St).

Metagenomics is the study of the metagenome – the collective genome of microorganisms obtained directly from environmental samples, as opposed to the approach of working with traditionally cultured bacteria. A metagenomics workflow classifies organisms based on a specific gene (i.e., 16S rRNA) and its specific region (in this case V5-V6 of the 16S rRNA gene, which does not overlap with plant DNA).

Credits

As editor, Walter Seidling would like to thank all those who have actively contributed to this Executive Report and all those who helped in the planning and realisation of the 6th Scientific Conference at Bucharest, Romania. Thanks are also extended to all those keeping the basic monitoring and research infrastructure of ICP Forests running in the field as well as virtually by feeding and controlling its data infrastructure.

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